Implementation of IoT-based Home Control and Monitoring System using Raspberry Pi and NodeMCUs

Kaung Nyunt San, Hlaing Thida Oo
University of Computer Studies, Yangon
mr.kaungnyuntsan@gmail.com, hlaingthidaroo@ucsy.edu.mm

Abstract

This system aims at controlling home appliances via Smartphone using Wireless communication protocol (Wi-Fi, MQTT) and Raspberry Pi as server system and NodeMCUs as client nodes. The user here will move directly with the system through a web-based interface over the web, whereas home appliances like lights, fan and door lock are remotely controlled through browser. An extra feature that enhances the facet of protection from fireplace accidents is its capability of sleuthing the flame in order that within the event of fireplace, associates an alerting messages, g-mails and notifications are sent to users. The server will be interfaced with relay hardware circuits that control monitor the appliances running at home. This system made easier by implementing automation and security along with the Internet of Things to create a system which will enable someone to remotely monitor and control some areas of a house remotely and securely from anywhere with minimum cost.

Keyword: *Raspberry Pi, NodeMCUs, MQTT, Internet of Things, Home Automation*

1. Introduction

Today, technology has become an integrated part of people's lives. It has and continues to influence many aspects of daily life and has allowed better social interaction, ease of transportation, the ability to indulge in entertainment and media and has helped in the development in medicine. The creation of many devices such as mobile phones, tablets and computers have caused many people to rely on technology to communicate with their friends, store information such as pictures, movies, documents, and music. The internet has become a common interface that many devices use in order to simplify the daily life of many people. Internet helps us to bring in with immediate solution for many problems and also able to connect from any of the remote places which contributes to overall cost reduction and energy consumption [1].

Home automation (also known as domotics) refers to the automatic and electronic control of household features, activity, and appliances. Home automation gives you access to control devices in your home from end devices (Smartphones, Computers, Tablets, etc.) anywhere in the world. The term may be used for isolated programmable devices, like thermostats and sprinkler systems, but home automation more accurately describes homes in which nearly everything -- lights, appliances, electrical outlets, heating and cooling systems -- are hooked up to a remotely controllable network [2][3].

From a home security perspective, this also includes alarm system, and all of the doors, locks, flame detectors, surveillance cameras and any other sensors that are linked to it [4]. Here we use a popular communication protocol called MQTT. MQTT is a message queuing telemetry transport. It is specifically designed for automation. It's having a very low footprint to send and receive data. So, it uses very less amount of data to send and receive between MQTT broker and MQTT clients. So MQTT is the protocol being used for this system [5]. And also use three Cloud services IFTTT, Remot3.it and Weather Underground. IFTTT service is used for send notifications, G-mails and messages to user. Remot3.it service support user remotely accesses to the system from anywhere. Getting weather information around home environment from Weather Underground service.

2. Internet of Things

The Internet of things (IoT) can be defined as connecting the various types of objects like smart phones, personal computer and Tablets to internet, which brings in very newfangled type of communication between things and people and also between things. The IoT-based architecture provides

high-level flexibility at the communication and information. With the introduction of IoT, the research and development of home automation are becoming popular in the recent days. Many of the devices are controlled and monitored for helps the human being. Additionally, various wireless technologies help in connecting from remote places to improve the intelligence of home environment. An advanced network of IoT is being formed when a human being is in need of connecting with other things. IoT technology is used to come in with innovative idea and great growth for smart homes to improve the living standards of life [6].

3. Proposed System

Every user who is experienced in the existing system may think of a system that may add more flexibility and run with some common applications such as android. This work is designed in such a way to avoid the disadvantages of the existing system. The proposed system supports more elasticity, comfort capacity and safety.

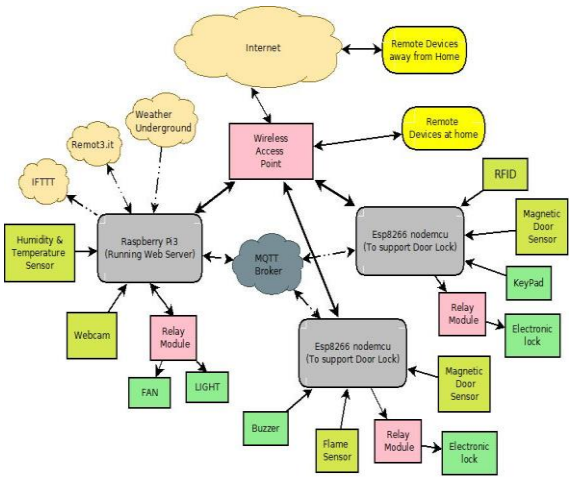


Figure 1. Block Diagram of Proposed System

The block diagram and architecture of proposed system is shown in Fig. 1 and Fig. 2. The system can separate into three main parts Front Door, Back Door and Main Server. All main parts are connected to Wireless Access Point and they communicate each other wirelessly through MQTT Protocol to exchange information.

The main objective is to design and to execute a cost effective and open source home automation system that's capable of leading most of the home and sustain the house automation system. The predictable system contains a great elasticity by using wireless reliable technology to interconnecting various modules to the server of home automation system. This in turn reduces the deployment cost; will add to the flexibility of advancement, and system reconfiguration. The proposed system can make use of wireless LAN (Local Area Network) connections between various sensors, hardware modules and server, clients and various communication protocols between users and server.

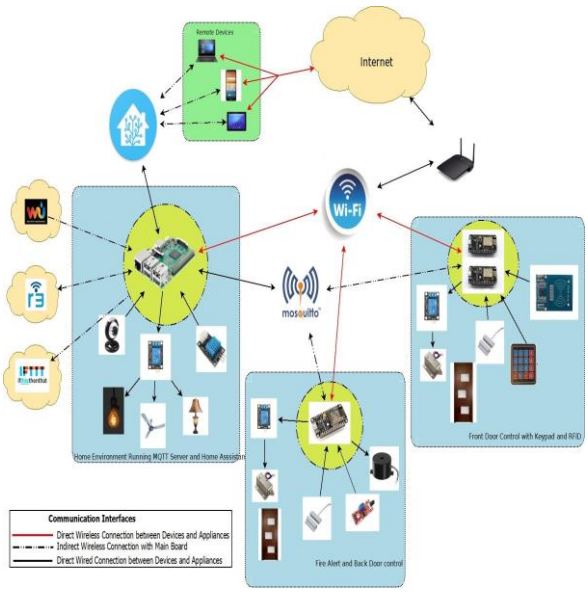


Figure 2. Architecture of Proposed System

Front Door part is running with two NodeMCUs. One NodeMCU is connect to the MQTT Broker as MQTT Client to exchange data. The other NodeMCU is to support user multi-access to control the door lock. This part contains Magnetic-Door sensor sensing the status of door OPEN/CLOSED, Electronic door lock to LOCK/UNLOCK the door and Relay Module to control Electronic door lock, which can be controlled with RFID or Keypad to open the door. Back Door part is running with one NodeMCU as MQTT Client connect to MQTT broker and exchange data like Front Door part. Also adding Fire Alert in this part to sense the flame of fire with flame sensor and triggered on buzzer if there is any fire accident detected. Main Server part is running with Raspberry Pi that support User Interface to control home appliances, monitor the situation of home through **Home Assistant** Platform. Home appliances, Humidity & Temperature Sensor, Webcam and Cloud Services are connected to Raspberry Pi. Alert critical status of home to user using IFTTT Cloud service and also run MQTT broker to support communication channel within

main parts [7]. All the components used in this system can be seen in Table 1.

Table 1. Component List of System

Component Lists		
No	**Device Name**	**Count**
1	Raspberry Pi	1
2	SD card	1
3	NodeMCU	3
4	Sim Router	1
5	Magnetic Door Sensor	2
6	DTH11 Temp Sensor	1
7	Relays (4 Channels)	3
8	IR Flame sensor	1
9	Buzzer	1
10	Keypad	1
11	RFID Card Sensor Module	1
12	Solenoid Electronic Lock	2
13	Webcam	1
14	Power supply (5v, 12v)	2
15	small access (led, jumper)	1
16	Fan	2
17	LED light	5

4. System Design

4.1. Sensors and Camera Interfacing

The sensors collect and relay different information about the environmental status in the house to the central unit. The different sensors being used are:

i. DHT11 digital temperature and humidity sensor is a composite Sensor contains a calibrated digital signal output of the temperature and humidity. The sensor includes a resistive sense of wet components and NTC temperature measurement devices, connected with a high-performance 8-bit microcontroller. So, it is used for sensing the temperature and humidity of Room.

ii. Magnetic-Door sensor is essentially a reed switch, encased in an ABS plastic shell. Normally the reed is 'open' (no connection between the two wires). The other half is a magnet. When the magnet is less than 13mm (0.5") away, the reed switch closes. They're often used to detect when a door or drawer is open, which is why they have mounting tabs and screws.

iii. An electronic lock (**or electric lock**) is a locking device which operates by means of electric current. Operating the lock can be as simple as using a switch. Electric locks are sometimes stand-alone with an electronic control assembly mounted directly to the lock. Electric locks may be connected to an access control system and can also be remotely monitored and controlled, both to lock and unlock. In this system using RFID and Keypad to access the Electric lock to lock or unlock.

iv. RFID stands for Radio-Frequency Identification. The acronym refers to small electronic devices that consist of a small chip and an antenna. The chip typically is capable of carrying 2,000 bytes of data or less. The RFID device serves the same purpose as a bar code or a magnetic strip on the back of a credit card or ATM card; it provides a unique identifier for that object. And, just as a bar code or magnetic strip must be scanned to get the information, the RFID device must be scanned to retrieve the identifying information. The electronic lock unlocks if identifying information for RFID card is correct with predefined information.

v. Keypad is a set of buttons or keys bearing digits, symbols and/or alphabetical letters placed in order on a pad, which can be used as an efficient input device. A keypad may be purely numeric, as that found on a calculator or a digital door lock, or alphanumeric as those used on cellular phones. The electronic lock also can unlock electronic lock by typing correct key string (password) on keypad.

vi. The **fire detection sensor** consists of flame sensor which is designed to detect and respond to the presence of a flame or fire. If there is any fire accident this will help to take immediate actions like activating the alarm (buzzer) and sending the fire alarm status to MQTT broker.

vii. Webcam is attached to run Live Streaming Video server on **RPi** to view and check the real-time status of home environment like CCTV. If user get any notifications about home situation user can immediate action remotely using smart phone through Internet [8].

4.2 Raspberry Pi and NodeMCU

The Raspberry Pi is a low-cost credit card sized single board computer which contain developed by raspberry pi foundation. NodeMCU is an open source IoT platform, it includes firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module.

The core of the home automation system is this minicomputer (Raspberry Pi 3). I used NodeMCU to perform relevant actions based on the sensor input and getting input from the user to control electronic lock.

4.3 Wi-Fi Router Configuration

The Wi-Fi unit provides the medium for communication. It can be also configured to make security services. The Wi-Fi should be configured with a certain address and user commands will be directing through Wi-Fi unit. For getting static ip address edit using "sudo nano /etc/network/interfaces" for configuring Wi-Fi with raspberry-pi and automatically giving DHCP ip addresses to NodeMCUs. The Raspberry pi configuration using raspi-config command is shown in the Fig. 3.

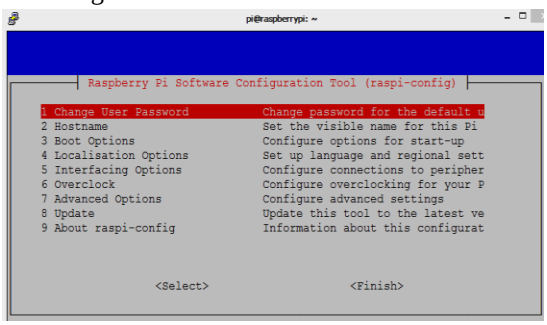


Figure 3. Raspberry Pi Configuration

4.4 MQTT Protocol

MQTT stands for message queuing telemetry transport. Unlike COAP, TCP, UDP, it is used because MQTT specializes in low-bandwidth, high-latency environments; it is an ideal protocol for machine-to-machine (M2M) communication [9]. Table 2 describes benefits and dis-advantages of MQTT protocol.

Table 2. Facts of MQTT

Facts of MQTT	
Benefits	**Dis-advantages**
Information Independent Nodes	Central Broker
Time Decoupling	TCP
Synchronization decoupling	Wake-up Time
Security Analysis	
MQTT Quality of Service levels	

4.4.1 MQTT Method and Testing

Now go ahead and install Mosquitto proper. There are three packages:

- mosquitto is the MQTT broker (i.e. server running on **RPi**)
- mosquitto-clients are the command-line clients
- python-mosquitto are the Python bindings

The next step is to test the mosquitto and the publisher. In separate terminal windows do the following:

Start the broker: mosquitto

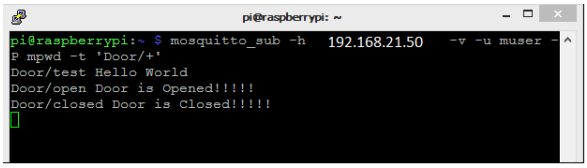
i > Start the command line subscriber:

- **mosquitto_sub -h 192.168.21.50 -u muser -P mpwd -t 'Door/+'**

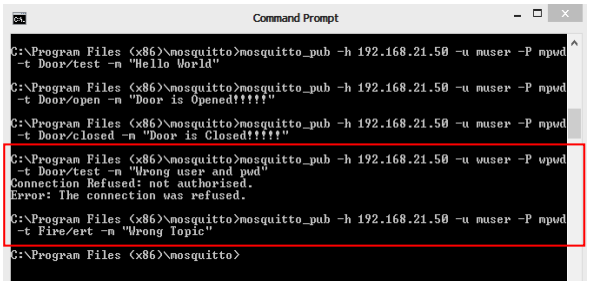
ii > Publish test messages with the command line publisher:

- **-mosquitto_pub -h 192.168.21.50 -u muser –P mpwd -t Door/test -m "Hello World"**
- **-mosquitto_pub -h 192.168.21.50 -u muser -P mpwd -t Door/open -m "Door is Opened!!!!!"**
- **-mosquitto_pub -h 192.168.21.50 -u muser -P mpwd -t Door/closed -m "Door is Closed!!!!!"**
- **-mosquitto_pub -h 192.168.21.50 -u wuser -P wpwd -t Door/test -m "Wrong user and pwd"**
- **-mosquitto_pub -h 192.168.21.50 -u muser -P mpwd -t Fire/ert -m "Wrong Topic"**

iii > As well as seeing both the subscriber and publisher connection messages in the broker terminal the following should be printed in the subscriber terminal:



(a)Mosquitto subscriber



(b)Mosquitto publisher

Figure 4. MQTT Testing

Total five publisher messages are published from publisher side but only first three published messages accepted by subscriber side. Because of wrong user and password at fourth published message and different publishing topic at fifth published message [10][11].

4.5 Home Assistant

Home Assistant is an open-source home automation platform running on Python 3. Track and control all devices at home and automate control. Perfect to run on a Raspberry Pi. Home Assistant will track the state of all the devices at home. Control all your devices from a single, mobile-friendly, interface. Home Assistant allows you to control all your devices without storing any of your data in the cloud.

Support many components is provided by the Home Assistant community. All the devices and components connected with Home Assistant Platform can be easily control and monitor through user interface (UI). Users can access Home Assistant UI to control and managed home from any devices that can access web-service.

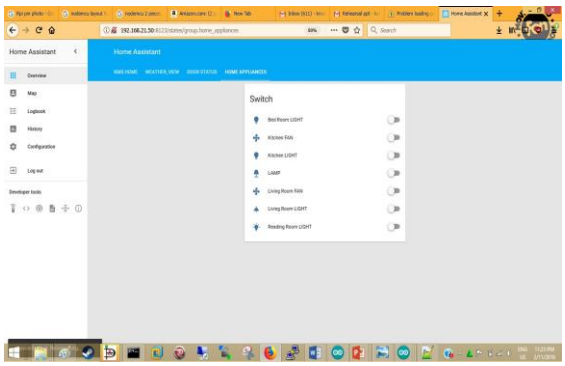
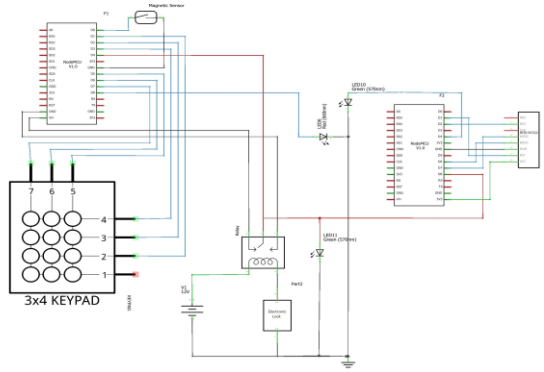


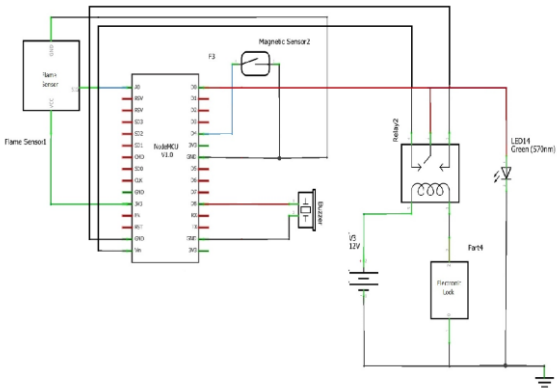
Figure 5. Sample Home Assistant UI

4.6 Circuit Design of the System

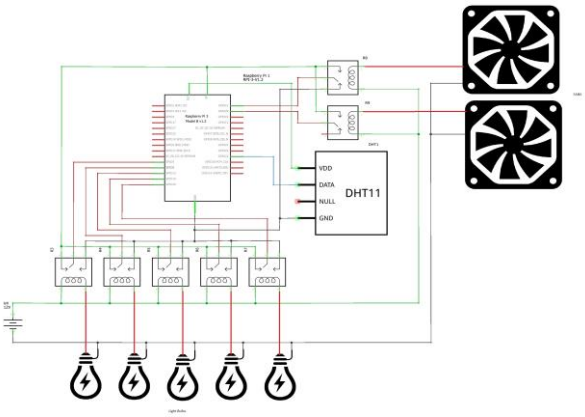
The circuit design of the whole system can be separated into three-parts (a) Front Door Part, (b) Back Door Part and (c) Main Part.



(a) Front Door Part



(b) Back Door Part



(c) Main Part

Figure 6. Circuit Design of System

5. Implementation Details

The implementation of this work starts with writing Raspbian-OS image to SD card and starting the operating system with the necessary configurations. The various configurations which can be done are such as changing the password for default user, choosing whether to boot into a desktop environment, scratch, or the command line, enabling camera etc. The configuration settings are done according to the user's need [12].

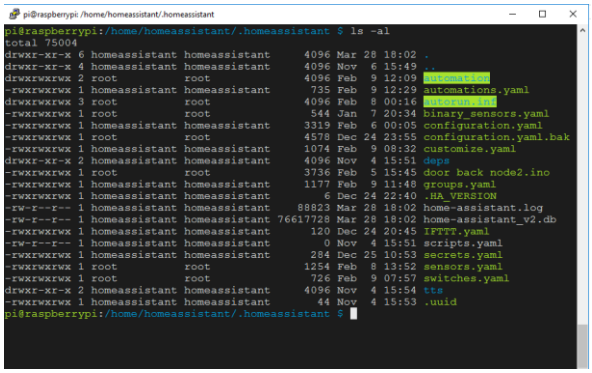


Figure 7.1. Home Assistant Config-files

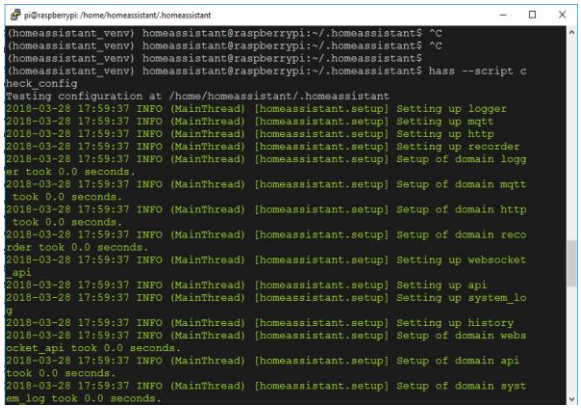


Figure 7.2. Checking Config-files

After the configuration files and settings are done, checking the Config-files with "hass –script check_config" command to sure no error in Config-files. And also need to check Mosquitto-service and Home-Assistant service are running well. All the information and checking results from terminal are shown in Fig. 7.1, Fig. 7.2 and Fig. 7.3.

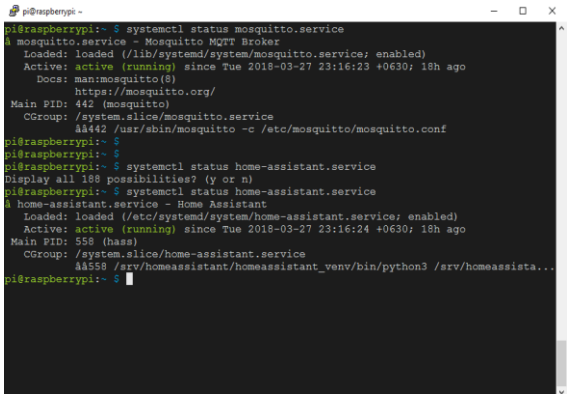


Figure 7.3. Checking Mosquitto and Home Assistant services

(a) Front Door Part **(b) Back Door Part**

(c) Main Part

Figure 8. Hardware Implementation of the System

The System is designed in such a way that the sensors are distributed in different parts of the house, and these sensors send real time continuous data to the main central board **RPi** wirely or wirelessly. The microprocessor contains condition of statement which executes a set of functions continuously. These functions include operations like automatic switching on/off of certain selected lights, performing requested actions like switching on/off of a light, fan, etc. performing emergency actions like sounding the alarm & notifying the user. A web portal is being created where the devices can be controlled and monitored. The same can be implemented in any end devices for continuous monitoring and control. If there is any sudden fire attack, user can check home through Webcam and how dangerous it is, simultaneously sending alert message to user is implemented [13].

A web page is designed such that we can control and monitor the home. The same can be implemented in any end-devices can access web services where we can take immediate action if there

is any emergency as well can control and monitor the home from remote places. The raspberry pi home page where the user can login with username and password is shown in the Fig. 9.

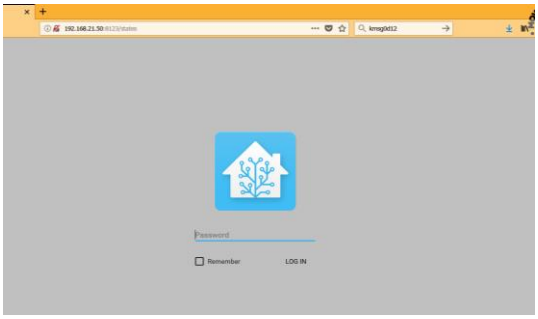


Figure 9. Home Assistant Login Page

After getting logged into home automation system by means of user name and password, the various information's are visible in one place. We can view status of all lights, fans, automations in home whether they are turned ON/OFF. The same can be implemented in end devices for continuous monitoring for home environment. We can view all the rooms in the home with various devices, where we can select devices and door locks which we want to control.

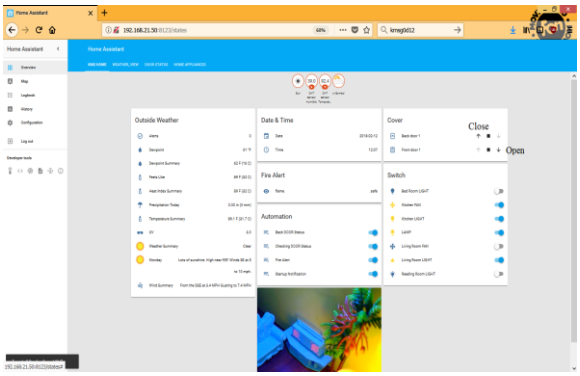


Figure 10. Complete UI for Home Assistant

Outside Weather Information, Living Room Temperature, Fire Alert, Date & Time, Home Monitoring Output and controllable Switches, Door Locks and Automations can be seen in the Fig. 10. Now the devices can be turned ON/OFF by means of the users wish. The GPIO (General Purpose Input Output) is used by which the user can interface the various sensors and switches directly to **RPi** and MQTT protocol is used to connect wirelessly to **RPi**. As a result, we can view the change in the status of the devices by means of end devices [14].

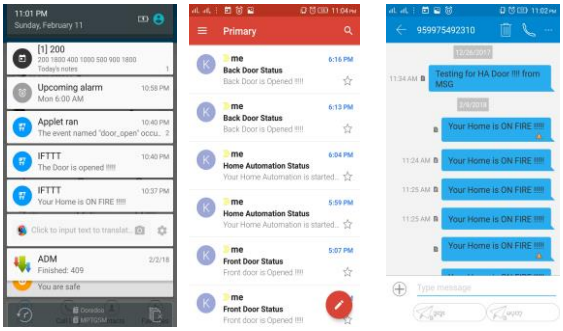


Figure 11. User Receives Notifications

The complete prototype of the system can be seen in Fig.12. One of the most important advantages of this system is that the devices can be controlled and monitored in any end devices that can access web-services. And user also get notification with real-time information about home when sensor is detected fire or someone forget to close the door [Fig. 11]. If house is really on fire system will automatically turn-off switches (shutdown electricity) and unlock all door lock at home. The control of various home appliances, door lock and monitor of the devices can be done by using end devices from Home Assistant UI through network (Internet).

Figure 11. Prototype of the system

6. Comparison from other Home Automation System

The benefits of home automation typically fall into a few categories, including savings, safety, convenience, and control. Additionally, some consumers purchase home automation for comfort and peace of mind. To support all of the above benefits in home automation system will cost a lot.

But my system will give consumers all of above benefits with very low cost.

The main building block of Home Automation System consisted of four basic elements: the sensor unit, processing unit, communication and power units. Some automation system sensor unit is running with Arduino UNO and ESP8266 module to sense data through connected sensor, sometime used Raspberry Pi as a sensor node just collecting sensor data and send to the main server. And the processing unit is running with high end PC to communicate with sensor units connected wired or wirelessly. In my system sensor unit is running only with NodeMCU to reduce cost and complexity of hardware implementation because it contains built-in ESP8266 WiFi module. The processing unit in my system is operating with Raspberry Pi because it is cheap, flexible, fully customizable, low power and programmable small computer board with built-in GPIO pins. Also, very powerful and easy to implement with many sensors and Compatible Boards [15] [16].

For end user control part other systems are platform dependency, the control and monitoring home only work on Android or IOS App. One advantage of my system is end user can easily control and monitor through browser that install on any device and platform like Android, IOS, Linux, Mac and etc. And my system can easily be extended by adding many sensor units running with NodeMCU.

7. Conclusion

In this paper, we have introduced the event of a home management and security system exploitation using Raspberry pi and Internet of Things technology. The focus was on reliable delivery of data from sensors to central main board using broker-based publish/subscribe messaging protocol MQTT, which main characteristics are low overhead, asynchronous communication, low complexity and low power. Using this protocol limitations resulting from constrained networks in rural areas are avoided. In proposed model the client producing data (publisher) sends data to the server which forwards data to end user devices. The system is suitable for real-time home safety monitoring and for remotely controlling the home appliances and protection from fire accidents with immediate solutions. The system may be employed in many places like banks, hospitals, labs etc. that dramatically cut back the hazard of unauthorized entry. Proof may be given to the safety department if any theft issue happens.

The various future applications may be used by controlling various household devices of house very easily with voice command, Industrial automation and management through internet, machine-driven fireplace exit systems and improvement of security problems in extremely restricted areas.

References

[1] Atzori, Luigi, Antonio Iera, and Giacomo Morabito. "The internet of things: A survey." Computer networks 54.15 (2010): 2787-2805.

[2] Al-Ali A. R., Rousan M. A., Mohandes M., "GSM-based Wireless Home Appliances Monitoring & Control System", IEEE International Conference, ISBN: 0-7803- 8482-2, (2004) 237-238

[3] Kelly, Sean Dieter Tebje, Nagender Kumar Suryadevara, and Subhas Chandra Mukhopadhyay. "Towards the implementation of IoT for environmental condition monitoring in homes." *Sensors Journal, IEEE* 13.10 (2013): 3846-3853.

[4] Assaf, Mansour H., et al. "Sensor based home automation and security system." Instrumentation and Measurement Technology

[5] MQTT-S A publish/subscribe protocol for Wireless Sensor Networks, Hunkeler, U.; IBM Zurich Res. Lab., Zurich; Hong Linh Truong ; Stanford-Clark, A, Communication Systems Software and Middleware and Workshops, 2008. COMSWARE 2008. 3rd International Conference

[6] "IoT Based Smart Security and Home Automation System" (2016), Ravi Kishore Kodali, Vishal Jain, Suvadeep Bose and Lakshmi Boppana, International Conference on Computing, Communication and Automation (ICCCA2016)

[7] "Cloud based low-cost Home Monitoring and Automation System", Shruthi Raghavan and Girma S. Tewolde, 2015 ASEE North Central Section Conference

[8] "A Low Cost Smart Security and Home Automation System Employing an Embedded Server and a Wireless Sensor Network", Semanur Karaca, Dr. Alper ŞİŞMAN, İbrahim SAVRUK, 2016 International Conference on Consumer Electronics.

[9] Eclipse Mosquitto. (2016, Feb. 12). [Online]. Available: http://mosquitto.org/-Commun vol. 4, no. 11, pp. 13121324, Jul. 2011.

[10] K. Tang et al., "Design and implementation of push notification system based on the MQTT protocol," in International Conference on Information Science and Computer Applications, September 2013.

[11] S.K. Shriramoju, J. Madiraju, and A.R. Babu, "An approach towards publish/subscribe system for

wireless networks," International Journal of Computer and Electronics Research, vol. 2.,pp. 505-508, August 2013.

[12] Raspberry Pi as a Wireless Sensor Node: Performances and Constraints, Vladimir Vujovic and Mirjana Maksimovic, Faculty of Electrical Engineering, East Sarajevo, Bosnia and Herzegovina, IEEE 2014

[13] "Wireless Home Security and Automation System Utilizing ZigBee based Multi-hop Communication", Mohd Adib B. Sarijari, Rozeha A. Rashid, Mohd Rozaini Abd Rahim, Nur Hija Mahalin, IEEE 2008 6th National Conference on Telecommunication Technologies.

[14] Ahmed El Shafee and Karim Alaa Hamed (2012), "Design and Implementation of a Wi-Fi Based Home Automation System", World Academy of Science, Engineering and Technology, Vol. 6.

[15] Rajeev Piyare, Department of Information Electronics Engineering, Mokpo National University, Korea. "Internet of Things: Ubiquitous Home Control and Monitoring System using Android based Smart Phone"

[16] Hamid Hussain Hadwan(M.E. Student, Mech. Mechatronics, SCOE, Pune, India) , Y. P. Reddy (Professor in Mech., SCOE, Pune, India). "Smart Home Control by using Raspberry Pi & Arduino UNO"